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14. ABSTRACT

The ADvanced CIRCulation Model, ADCIRC, and the HYbrid Coordinate Ocean Model, HYCOM, are coupled in the Northern Aegean Sea. Over its 62 km, the Dardanelles Strait connects the Aegean Sea to the Marmara Sea. The Dardanelles outflow spreads to the Aegean Sea as a buoyant plume showing seasonal characteristics. The unstructured nature of the ADCIRC mesh provides the resolution necessary to model flow in the narrow strait whose minimum width is about 1 km. During one-way coupling efforts, ADCIRC is initialized using interannual solutions for temperature, salinity, velocity and water surface elevation fields taken from a larger domain HYCOM-AMB model, covering the Aegean, Marmara and Black Seas. Experiments using the one-way coupled model system are targeted at early February and late May of 2003 representing typical winter-spring and summer-fall conditions, respectively.

15. SUBJECT TERMS

ADvanced CIRCulation Model, HYbrid Coordinate Ocean Model, bathymetry, Dardanelles Strait

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Modeling the Dardanelles Strait Outflow Plume Using a Coupled Model System

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***Abstract*— The ADvanced CIRCulation Model, ADCIRC, and the HYbrid Coordinate Ocean Model, HYCOM, are coupled in the Northern Aegean Sea. Over its 62 km, the Dardanelles Strait connects the Aegean Sea to the Marmara Sea. The Dardanelles outflow spreads to the Aegean Sea as a buoyant plume showing seasonal characteristics. The unstructured nature of the ADCIRC mesh provides the resolution necessary to model flow in the narrow strait whose minimum width is about 1 km. During one-way coupling efforts, ADCIRC is initialized using interannual solutions for temperature, salinity, velocity and water surface elevation fields taken from a larger domain HYCOM-AMB model, covering the Aegean, Marmara and Black Seas. Experiments using the one-way coupled model system are targeted at early February and late May of 2003 representing typical winter-spring and summer-fall conditions, respectively.**

I. Introduction

A number of semi-enclosed seas are connected to adjacent regional seas or the global ocean through shallow, narrow straits. Often these straits are not well-represented within global and regional scale ocean models and yet their dynamics are integral to the circulation patterns of the regional basin. A coupled model system is developed here to address this shortcoming by joining high resolution, unstructured grid models to structured grid, hybrid coordinate regional models. Application of the developed coupled model system to outflow dynamics of the Dardanelles plume entering the northern Aegean Sea provides a basis for evaluation.

An existing regional model of the Northern Aegean Sea presently represents the Dardanelles outflow as a point discharge into the basin, analogous to that of a river. The coupled model system presented here provides a more realistic representation of the three-dimensional outflow from the Dardanelles Strait into the northern Aegean Sea. Movement of the plume derived from the coupled model computations is contrasted with plume dynamics obtained from the model in which the Dardanelles is represented as river inflow. This comparison provides a sense of the importance of small-scale strait dynamics on the larger scale plume dynamics.

Within this paper, details of the coupled model system are presented for the Dardanelles-Northern Aegean Sea application. Sensitivity of the computed circulation to the initial fields in the coupled model system is investigated by considering initial values of the temperature and salinity forcing derived from two implementations of the regional model as well as in-situ data. Lastly a discussion of the plume behavior during winter and summer conditions, examining the influence of the coupled model representation of the plume is presented.

II. Coupled Model System

A. Dardanelles Strait Model

The Dardanelles Strait is a long and narrow, very shallow and strongly stratified strait that connects the Aegean Sea to the Marmara Sea basin. The strait is approximately 62 km in length with an average width of 4 km and an average depth of 55 m [1]. Geometry of the strait is captured with an unstructured mesh of linear triangles whose minimum side length is 20 m at the Nara Passage constriction. The Nara Passage is 1.2 km in width, resulting in at least 31 computational points available to capture cross-shore variability in the strait. The unstructured mesh extends eastward to the shelf region of the adjoining Marmara Sea, ending at a maximum depth of 90 m. Resolution at this open sea boundary ranges from 260 m near the land boundaries to 1.4 km in the open water. To the west lies the northern Aegean Sea where the mesh boundary extends well beyond the plume exit region. The mesh has a spatial resolution of 150 m near the plume outflow that expands to 6.5 km over deeper waters. The minimum water depth is set at 5 m. A graphic depicting the entire domain of the unstructured mesh is provided in Fig. 1. Over the water depth 41 stretched vertical coordinate layers are used. Fig. 2 shows the bathymetry in the Dardanelles Strait and over the Northern Aegean Sea.

The model applied over this unstructured mesh of triangles is the Advanced Circulation Model (ADCIRC). ADCIRC is a finite-element based shallow water equation model whose dynamics have recently expanded to include three-dimensional transport and mixing associated with density-driven circulation [2], [3]. Validation of this model for the classic density-driven lock-exchange problem is reported by [4].

All non-linear terms are active in the model. Vertical mixing is represented by using the Mellor-Yamada 2.5 level closure

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Fig. 1. Domain and unstructured mesh for the ADCIRC Dardanelles Strait model.

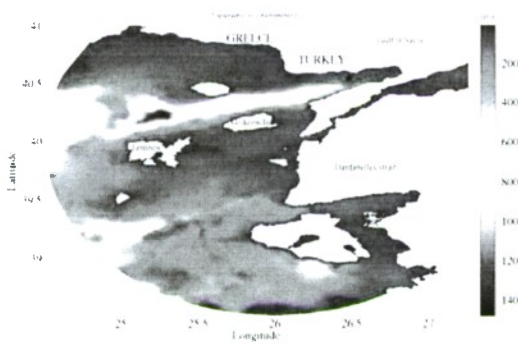

Fig. 2. The bathymetry of the Dardanelles Strait and the Northern Aegean Sea.

with a minimum vertical eddy viscosity coefficient of 0.00001. The model applies a linear slip at the ocean bottom in which the bottom friction is a linear function of the bottom velocity with a corresponding linear friction coefficient of 0.005. A spatially constant value of 0.00005 is used for free surface roughness and a value of 0.05 for the bottom roughness, constant over the horizontal. A spatially constant horizontal eddy viscosity is used for the momentum equations. The weighting parameter, *tau0*, in the generalized wave continuity equation is spatially variable with values of 0.005 in water depth greater than 200 m. For water depths between 1 m and 200 m, *tau0* is specified as 1/depth.

B. Atmospheric Model

Ocean-atmosphere coupling is introduced by coupling ADCIRC with the atmospheric component of the Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). COAMPS is a three-dimensional data assimilative model system comprised of data quality control, analysis, initialization and non-hydrostatic forecast model components [5]. A spherical projection is used with a $1/5^\circ$ grid resolution in the Europe2 domain of COAMPS that spans the latitudes and longitudes, [29 50]°N and [-15 40]°E, respectively. Components of the wind stress, calculated using wind velocity and a Garritt surface drag formulation, and the atmospheric pressure, reduced to mean sea level, are the meteorological variables computed by COAMPS and provided as forcing to ADCIRC. For simulations that extend beyond the scope of this paper, the total surface heat flux forcing is also applied using COAMPS-derived estimates for net shortwave and longwave radiation, and latent and sensible heat fluxes.

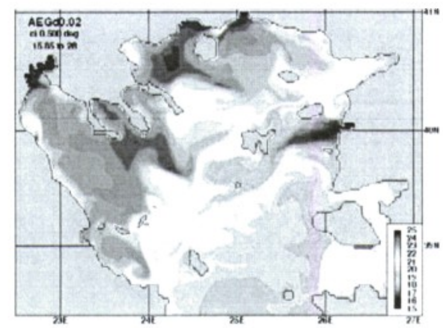

Fig. 3. The HYCOM-NAS model domain with May sea surface temperature (°C) using atmospheric forcing from POSEIDON.

C. Northern Aegean Model

One option for forcing at the western boundary of the ADCIRC Dardanelles Strait model is the ocean parameters computed from a HYbrid Coordinate Ocean Model of the Northern Aegean Sea (HYCOM-NAS). HYCOM-NAS is configured by [6] at a resolution of 1/50 degree ($\sim$ 1.8 km). The model domain shown in Fig. 3 extends southward to 38.5°N where the model is nested to a 1/25 degree regional HYCOM model of the Mediterranean Sea [7]. HYCOM applies the finite difference method over a structured grid to solve primitive equations using a unique hybrid vertical coordinate that allows the use of three vertical coordinate types (depth, terrain-following and isopycnal) [8]. The HYCOM-NAS model contains 20 hybrid vertical layers. Minimum depth in the model is 2.4 m while deep areas reach 1500 m. Forcing includes atmospheric data in the form of surface winds and surface temperature from the POSEIDON/SKIRON (1/10 degree) model [9]. At the Dardanelles entrance to the Aegean Sea a two-way inflow-outflow condition [10] prescribes seasonal transport rates and assigns fresh water river flow with a constant Black Sea water salinity of 0 psu. The upper layer is assumed to be half of the total water column depth ($\sim$ 25m) and uniform velocities are computed based on the defined transports. For simulations in this paper the HYCOM-NAS model applies the K-profile Parameterization (KPP) [11] vertical mixing scheme and the horizontal diffusion is based on Smagorinsky model [12].

D. Aegean-Marmara-Black Seas Model

A separate implementation of HYCOM which has a domain that spans regions of the Mediterranean, Aegean, Marmara and Black Seas, shown in Fig. 4, is named HYCOM-AMB. The model has an even finer spatial resolution of 1/75 degree

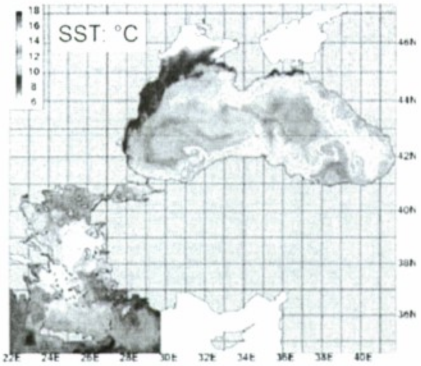

Fig. 4. The HYCOM-AMB model domain with January sea surface temperature.

($\sim$ 1.1 km) and 25 hybrid vertical levels, 14 of which are sigma levels. Bathymetry within the model has been edited to artificially open the Bosporus Strait (which connects the Black Sea to the Marmara Sea) and the Dardanelles Strait (which connects the Aegean Sea to the Marmara Sea). The HYCOM-AMB model is nested inside the 1/25 degree Mediterranean HYCOM [7] with the southern boundary located outside the Aegean Sea. Inter-annual simulations that include 2003 are initialized from a World Ocean Atlas 1/4 degree hydrography (temperature and salinity) and relaxed to climatology from the Mediterranean Sea along the southern boundary. Applied winds are from a wind product composed of ECMWF 40-year reanalysis plus the 0.5^o Navy Operational Global Atmospheric Prediction System (NOGAPS) 6-hour anomalies with QuikSCAT corrections to wind speed and stresses. The KPP vertical mixing model is again implemented for HYCOM-AMB model solutions used here.

E. Coupling Details

An approach for one-way coupling between the regional model, HYCOM and fine-scale strait model, ADCIRC is developed. HYCOM temperature, salinity, elevation and velocity components are all used to initialize a diagnostic ADCIRC model run in which the density field is held constant during tidal ramp-up. A prognostic computation in which winds, surface heat flux(when used), tides and the density structure all evolve in time is then initialized from the diagnostic solution. During the prognostic run, the same HYCOM variables are applied at the ADCIRC model open water boundaries as daily forcing. Steric height adjustments, computed using HYCOM elevations and HYCOM vertical temperature and salinity structure are applied over the water column to the 1000 m contour. The atmospheric forcing variables, i.e. wind stress and pressure are applied at the water surface every 3 hours. When activated, latent and sensible heat fluxes, and net short-wave and long-wave radiation are to be applied at the same frequency.

Fig. 5 shows the variables exchanged between each model in a schematic of the coupled model system. A temporally

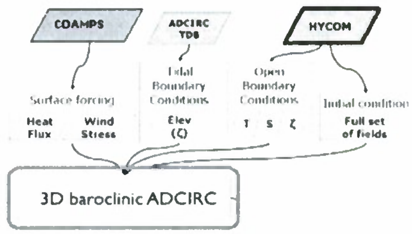

Fig. 5. The ADCIRC-HYCOM-COAMPS coupled model system.

invariant, spatial ramp or sponge layer is applied to wind and advection terms, over a distance of 12 km at the open boundaries, approximately 2 elements. The interpolation or extrapolation of HYCOM model solutions to ADCIRC model grid nodes for either initialization or boundary forcing follows a distance weighted interpolation scheme wherein the parameter values of the closest surrounding HYCOM grid points are used. If all HYCOM grid points surrounding an ADCIRC node fall on land, then a circular search is conducted expanding outward until a sea point on the HYCOM grid is encountered and its value applied. In the vertical, HYCOM layer average values are interpolated to a z-grid and then interpolated to the generalized, stretched coordinate native to the ADCIRC model.

III. Model Experiments

The strongly stratified, density driven two-layer flow in the Dardanelles presents a unique challenge for model coupling. Within a coupled model system, the high resolution model typically is aimed at representing shallow water or coastal dynamics that are initiated by coarsely defined fields from a regional model. Circulation and stratification patterns in the coastal regions are often an outgrowth of the larger scale regional circulation. So though coarse, initial fields from the regional model are representative of the underlying ocean dynamics. For the case here where dynamics of the coupled system is driven by details of the flow and stratification within a geometrically complex, shallow strait, the inability of the regional model to properly represent the underlying flow and density structure within the strait affects the quality and representativeness of the initial condition.

An initial set of coupled model experiments aims to determine sensitivity of the boundary and initial forcing on the modeled solution of flow and stratification within the Dardanelles Strait as well as the movement of the plume itself once in the northern Aegean Sea. Table I details three experiments that vary source of the initial temperature and salinity fields and source of the boundary data applied at the eastern (Marmara) and western (Aegean) open boundaries. Available sources over the Aegean Sea and at the western boundary are the HYCOM-NAS and HYCOM-AMB models. Within the Dardanelles Strait, initialization is derived either from HYCOM-AMB or observational data. For this case the observational data is from CTD and scanfish measurements

TABLE I

MODEL FORCING EXPERIMENTS

No	Initialization			Boundary Forcing	
	Aegean	Dardanelles	Marmara	Aegean	Marmara
1	AMB	AMB	AMB	AMB	AMB
2	AMB	CTD	CTD	AMB	AMB
3	NAS	CTD	CTD	NAS	AMB

collected as part of the TSS08 and TSS09 Sea Trials. In all cases the HYCOM-AMB model is applied at the eastern boundary in the Marmara Sea. Note at the time of this writing the third model forcing experiment (e.g. No. 3) shown in Table I has not yet been completed.

ADCIRC model simulations for winter-spring conditions span the same 10-day time period as the observations, 08-18 February, but for the year 2003 to coincide with available HYCOM-NAS solutions. The diagnostic run is 4 days in length and the prognostic run extends 7 days beyond the diagnostic simulation. Unfortunately, no measurements are yet available for the summer time period, so ADCIRC model experiments for summer have coupling described by experiment No. 1 in Table I with a 4-day diagnostic simulation and a 10-day prognostic simulation starting on 24 May 2003 and ending 2 June 2003.

IV. RESULTS

To better understand and interpret model solutions, a brief discussion of the dynamics of the Dardanelles Strait is presented. Density differences between the Aegean Sea waters and the Black Sea waters govern the two-layer stratification in the Dardanelles Strait. The denser Aegean sea waters flow in a lower layer through the Dardanelles into the Marmara Sea while the fresher Black Sea waters flow at the surface in the opposite direction; a strong pycnocline separates these two layers [1]. The lower layer flow out of the Dardanelles Strait sinks into the deep basins of the Marmara Sea as a turbulent plume [13]. Seasonal variations in the lower layer water density flowing into the Marmara Sea through the Dardanelles Strait results in different forms of the density current in the area [14]. A theoretical study by [15] represents flow in the Dardanelles Strait as a lock-exchange problem using a 2-D non-hydrostatic numerical model. Alternatively [16] studied flow in the Dardanelles Strait using a 3-D primitive equation numerical model and showed that the turbulent friction and mixing at the narrowest location of the strait, i.e. the Nara Passage, strongly affects the dynamics.

A. Seasonal Behavior of the Dardanelles Plume

The Dardanelles plume outflowing into the Aegean Sea shows a seasonal variability as seen in the HYCOM-NAS results. During typical winter-spring conditions, the Black Sea waters at the surface flow westward out of the Dardanelles Strait between the Lemnos and Gökçeada Islands and remain largely contained in the Northeastern Aegean as shown in Fig. 6. For typical summer-fall conditions, the plume spreads through a wider area in the Aegean Sea reaching deep basins

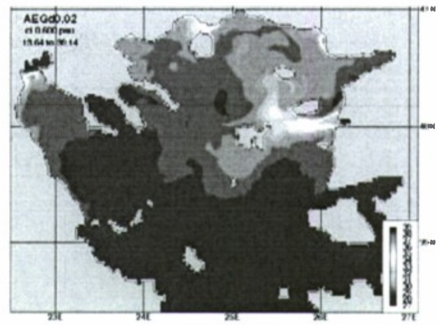

Fig. 6. Sea surface salinity in the Aegean Sea in March 2003.

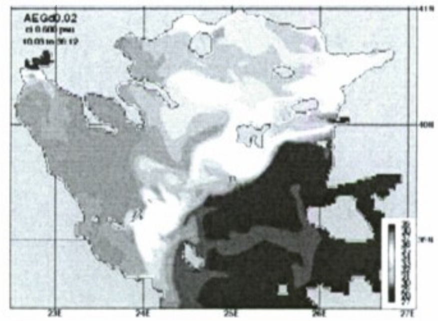

Fig. 7. Sea surface salinity in the Aegean Sea in May 2003.

as well as coastal areas away from the Dardanelles Strait as shown by HYCOM-NAS results in Fig. 7. Variability in the spread of the plume is not only due to differences in the stratification within the Dardanelles Strait but is also caused by differences in the wind field over the Aegean Sea and near the Dardanelles Strait [10].

B. Sensitivity of Dardanelles Plume to the Initial Conditions

The spread of the Dardanelles plume in the Aegean Sea is mainly controlled by the stratification within the strait [6]. Therefore, the initialization of the temperature and salinity fields becomes important for accurate prediction of the vertical variability of these variables as well as the density. As mentioned previously, the Dardanelles Strait is not included within the HYCOM-NAS model, rather it is represented by a river flux into the domain. The HYCOM-NAS model assumes constant, fresh salinity input at the location of the Dardanelles entrance into the Aegean Sea. In reality, the Black Sea waters flowing into the Aegean Sea through the Dardanelles Strait show a seasonal variability in freshness. For the HYCOM-AMB model, the Dardanelles Strait is represented by an idealized channel. The HYCOM-AMB model assumes a constant depth of the strait and does not resolve the geometry of the strait, particularly the critical Nara Passage, which leads to an oversimplification of the stratification in the strait. To examine the sensitivity of ADCIRC computations to the initial condition and to ascertain the level to which accurate representation of the internal strait dynamics is needed, the ADCIRC Dard-

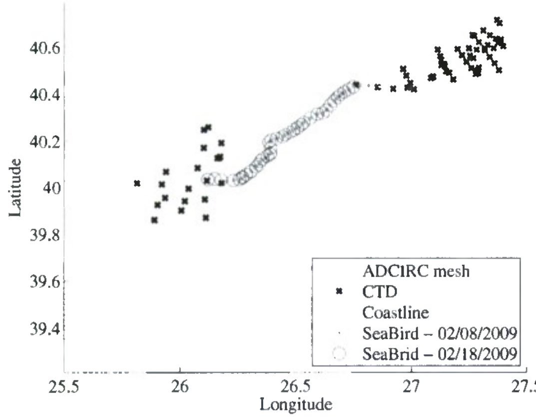

Fig. 8. The measurement locations during Sea Trial TSS09 used to generate initial fields for ADCIRC by an optimal interpolation algorithm.

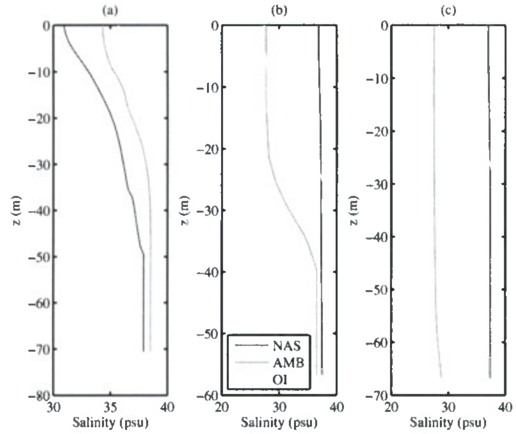

Fig. 9. The depth variation of salinity in the initial fields for the coupled model taken from HYCOM-NAS (NAS-blue), HYCOM-AMB (AMB-red) and optimally interpolated observations (OI-green) at (a) the west end of the Dardanelles Strait (26.21°E) nearest the Aegean Sea, (b) the east end of the Dardanelles Strait (26.67°E) entering the Marmara Sea, and (c) the east end of the coupled model domain in the Marmara Sea (27.26°E).

anelles Strait model is initialized from both HYCOM-AMB solutions and observational data in the Dardanelles Strait. Optimal interpolation is used to merge different measurement data sets collected during the TSS09 field excursion and to interpolate those measured data onto the ADCIRC mesh nodes in the Dardanelles Strait. The measurement locations used during the optimal interpolation analysis are shown in Fig. 8. All measurements though actually collected during a ten day span from 8-18 February 2009 are treated as if they are collected coincidently on 8 February 2009.

The three sources for initial conditions are examined by considering the depth variation of salinity at both ends and in the middle of the Dardanelles Strait as shown in Fig. 9. In Fig. 9(c) the salinity variation from both HYCOM-AMB (red) and HYCOM-NAS (blue) have no vertical structure in the Marmara Sea. In contrast, the vertical structure of the optimally interpolated measurements (green) in Fig. 9(c) indicate fresher Black Sea waters in the first 20 m below the surface and saltier Aegean Sea waters below 30 m with a sharp halocline separating the two layers. Even though salinity from both HYCOM-AMB and HYCOM-NAS is nearly constant over depth, the former matches the measured value at the surface while the latter matches the measured value at the bottom. Excessive mixing of the Black Sea waters with the Aegean waters in the Marmara Sea in the HYCOM-AMB solution result in a salinity that more closely matches the outflowing Black Sea water. On the other hand, HYCOM-NAS does not include the Dardanelles Strait or the western Marmara Sea and therefore salinity values reflect the closest sea points on the HYCOM-NAS grid which happen to be located in the Gulf of Saros in the Northeastern Aegean Sea. The consequence of this extrapolation is a salinity value for HYCOM-NAS that is reflective of Aegean Sea waters.

At both ends of the Dardanelles Strait (Fig. 9 (a) and (b)), salinity in the initial fields from HYCOM-AMB and the observations are similar though HYCOM-AMB introduces a much deeper halocline. Salinity from the HYCOM-NAS initialization field still shows no depth variation at the east end of the Dardanelles Strait, as shown in Fig. 9(b). On the west end of Dardanelles Strait, the salinity from HYCOM-NAS is more realistic but the surface value is much smaller than that recorded by the measurements. The representation of the Dardanelles Strait as a fresh (zero salinity) river inflow is not an accurate depiction when compared to the observed salinity.

From this examination of the salinity profiles, one can infer that initialization of the coupled model runs with a HYCOM-NAS solution may not result in an accurate representation of the salinity and density distribution in the Dardanelles Strait. Furthermore, even if the surface and bottom salinities computed by HYCOM-AMB within the Dardanelles Strait are reasonable, since the depth structure of the salinity and by inference the density is not maintained at the eastern boundary of the coupled model system, the coupled model systems ability to represent the two-layer flow dynamics may be compromised.

Sea surface salinity at the end of the diagnostic run period are shown in Fig. 10 and Fig. 11 using initial temperature and salinity fields from the optimally interpolated observations and the HYCOM-AMB solution, respectively. Clearly, initial condition specification within the Dardanelles Strait has a strong effect on the computed pathway and spreading of the Dardanelles plume into the Aegean Sea. For the ADCIRC Dardanelles Strait model initialized by HYCOM-AMB (Fig. 11), the plume spreads westward past the Gökçeada Island. Alternatively, if initial fields are derived from the measurements by optimal interpolation, movement of the plume within the Aegean Sea is limited to a very small region at the west end of the Dardanelles Strait. The scenario in Fig. 11 agrees best

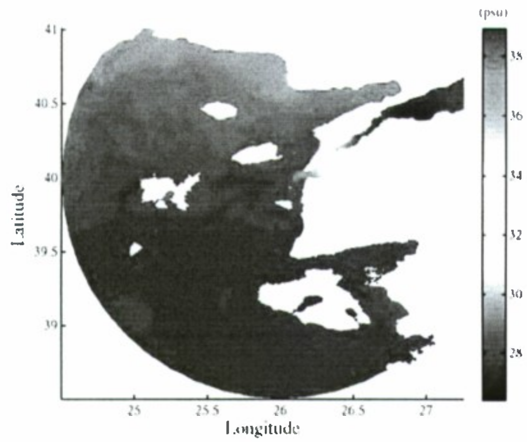

Fig. 10. The final result of a 7-day prognostic run for sea surface salinity over the Dardanelles Strait and the Northern Aegean Sea in early February 2003 using optimally interpolated observations as initialization in the Dardanelles Strait.

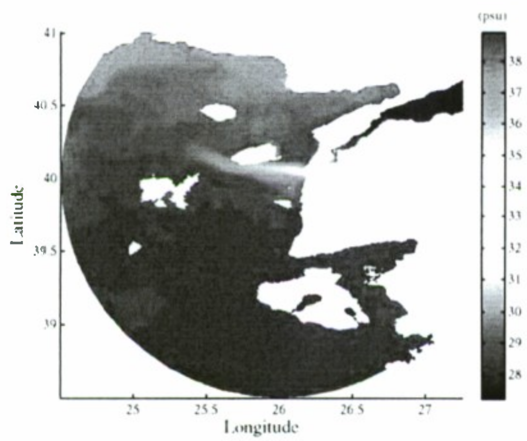

Fig. 11. The final result of a 7-day prognostic run for sea surface salinity over the Dardanelles Strait and the Northern Aegean Sea in early February 2003 using HYCOM-AMB as the initial condition.

with the HYCOM-NAS result for the same day as shown in Fig. 12.

C. Influence of the Coupled Model System on Plume Dynamics

Computed solutions from the coupled model system using forcing from HYCOM-AMB as described by experiment No. 1 in Table I are compared here to results from the HYCOM-NAS model. The decision to use initial fields from HYCOM-AMB is dictated by the unavailability of observations for the summer time period and the desire to maintain similarity between summer-winter plume dynamics comparisons. The initial sea surface salinity throughout the domain for the summer prognostic simulation, i.e., the final of a 4-day diagnostic simulation, is shown in Fig. 13. The Black Sea water flowing into the Dardanelles Strait from the Marmara Sea has a salinity

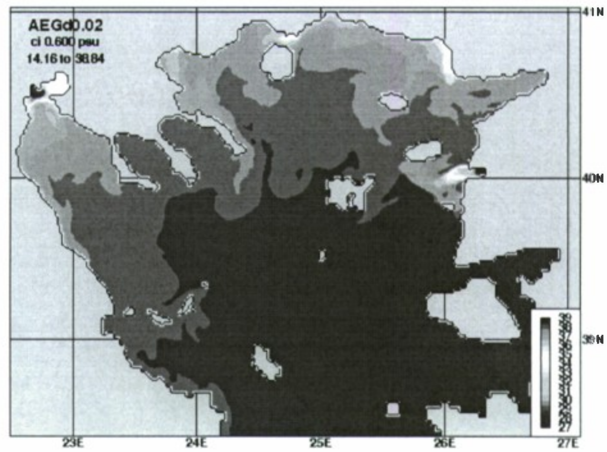

Fig. 12. The HYCOM-NAS result for sea surface salinity on February 08, 2003.

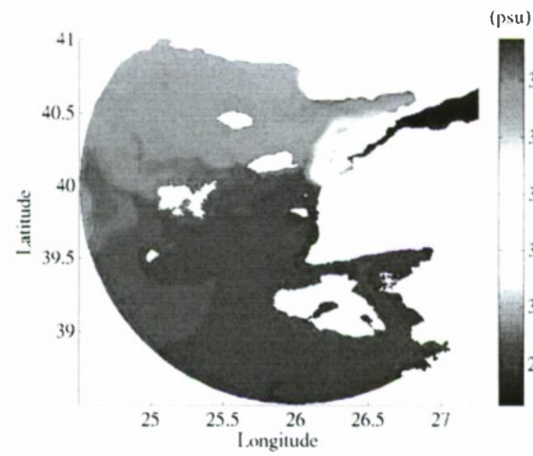

Fig. 13. The initial condition of sea surface salinity for a 10-day summer prognostic run in the Aegean Sea starting May 24, 2003.

($\sim$28 psu) which is much lower than the saline Mediterranean water in the Aegean Sea ($\sim$40 psu). The change in sea surface salinity within the Dardanelles Strait indicates vertical mixing of the Black Sea water flowing westward at the surface with Aegean sea water flowing eastward in the bottom layer. Upon exiting into the Aegean Sea, the Dardanelles plume initially flows north towards the Gulf of Saros and then spreads northward of Gökçeada Island in the Northern Aegean Sea.

At the end of the 10-day prognostic summer solution, examination of the sea surface salinity in Fig. 14 shows that the Dardanelles plume is well spread and mixed in the Northern Aegean Sea and follows along the coasts of Turkey and Greece. A comparison with the HYCOM-NAS results in Fig. 15 indicates that both models perform similarly with regard to the spread of the plume. However, the fresher water salinity value used for the Dardanelles inflow in the HYCOM-NAS model is much less than the salinity of the Dardanelles

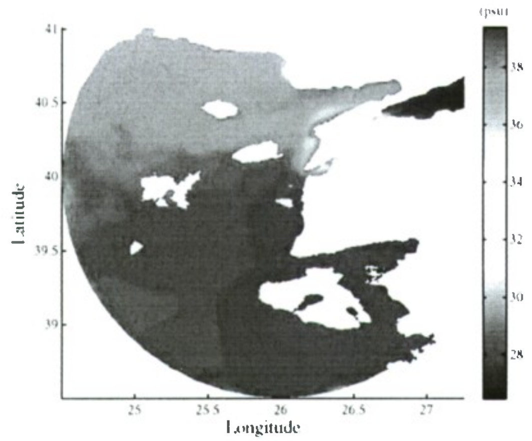

Fig. 14. The final result of a 10-day summer prognostic simulation for sea surface salinity in the Aegean Sea on June 2, 2003.

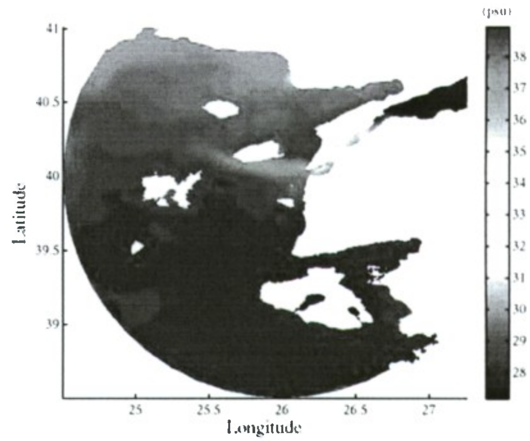

Fig. 16. The final result of an 7-day prognostic simulation for sea surface salinity in the Aegean Sea on February 18, 2003.

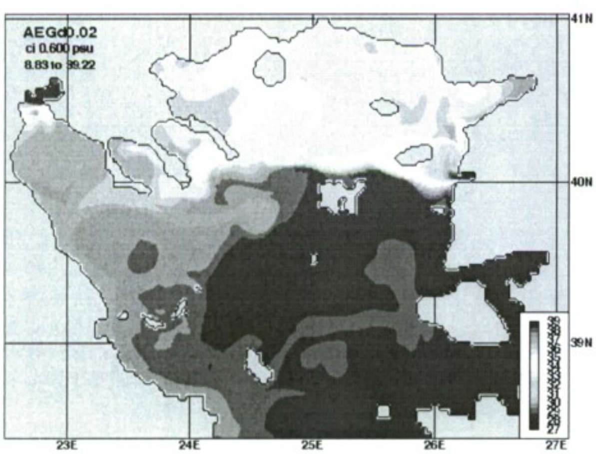

Fig. 15. The HYCOM-NAS result for sea surface salinity on June 2, 2003.

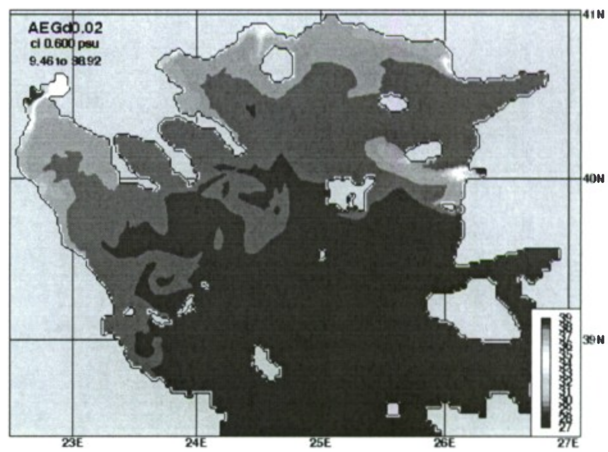

Fig. 17. The HYCOM-NAS result for sea surface salinity on February 18, 2003.

outflow into the Aegean as predicted more realistically by the ADCIRC Dardanelles Strait model.

To contrast the summer plume dynamics, the sea surface salinity at the beginning and end of a 7-day prognostic coupled model run for winter 2003 are shown in Fig. 11 and Fig. 16, respectively. The Black Sea waters are observed to follow a westward pathway just south of Gökçeada Island. Unlike summer conditions, the plume does not affect a wide area of the Northern Aegean near the shores of Turkey and Greece. The coupled model system results in very little spreading of the Dardanelles plume in the Aegean Sea and the sea surface salinity in Fig. 16 closely resembles the result obtained from HYCOM-NAS for the same day as shown in Fig. 17. Recall that the coupled model was initialized by HYCOM-AMB over the entire domain.

V. Conclusion

Dynamics of the stratified flow in the Dardanelles Strait and the spread of the Dardanelles plume in the Aegean Sea is studied by a coupled model system, ADCIRC-HYCOM-AMB. The modeled plume dynamics are shown to be rather sensitive to the initial representation of salinity stratification in the Dardanelles Strait. Three sources for the coupled model initialization are examined: HYCOM-AMB with an idealized geometry for the Dardanelles Strait, HYCOM-NAS which treats Dardanelles outflow into the Aegean Sea as fresh river discharge and observations from the TSS09 sea trials from 08-18 February 2009. Salinity fields from the HYCOM model (AMB and NAS) are observed to have a uniform salinity distribution over the water column at the eastern boundary of the coupled model domain in the Marmara Sea, which is unrealistic given the known two-layer stratified flow conditions. The optimally interpolated measurements are able to

introduce a realistic depth variation for salinity when used as initialization for the coupled model. A model inter-comparison between the coupled model results forced by HYCOM-AMB and the HYCOM-NAS solutions show good agreement in capturing the contrasting spreading characteristics of the Dardanelles plume for summer versus winter conditions. The work presented establishes credibility for the coupled ADCIRC-HYCOM model for capturing two-layer estuarine flow, a first for the newly developed baroclinic version of the ADCIRC model, and serves as a basis for more detailed studies of the Dardanelles plume and dynamics within the strait itself.

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